DOCUMENT RESUME

ED 099 196 SE 017 206

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TITLE	Process Versus Content in Elementary Science Teaching.
INSTITUTION	Syracuse Univ., N.Y. Dept. of Science Teaching.
PUB DATE	73
NOTE	24p.
EDRS PRICE	MF-$0.75 HC-$1.50 PLUS POSTAGE
DESCRIPTORS	Cognitive Development; Curriculum; *Elementary School Science; Elementary School Students; *Instruction; *Process Education; *Science Education; Science Instruction; Teacher Education

ABSTRACT

The purpose of the monograph was to determine if the process of science or the content of science should be emphasized in elementary school science teaching. The discussion attempts to show why process, and not content, should be the primary emphasis in elementary school science teaching by examining the history of elementary school science in the United States, cognitive development, and the preparation of teachers. The results indicate that educators regard the development of competence in use of the scientific method and the development of the scientific attitude the most important objectives of science instruction. Developmental psychologists such as Montessori, Piaget, and Bruner believe that child cognition is enhanced when pupils use the processes of science. Finally, there is evidence that elementary school teachers can be better trained to teach a process-oriented curriculum because it requires little understanding of the concepts and principles of science and does not require teachers to keep up to date with scientific information. (Author/BR)

PROCESS VERSUS CONTENT IN ELEMENTARY SCHOOL SCIENCE TEACHING

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A monograph of the Department of Science Teaching
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INTRODUCTION

Should the process of science or the content of science be emphasized in elementary school science teaching? The content of science—the facts, concepts, laws and principles of science which are the end products of scientific investigation, has been taught in most elementary school science programs in the United States. New elementary science programs have appeared since 1960 which de-emphasize content and stress the processes which scientists use to gather and use information. Observing, classifying, using numbers, experimenting, controlling variables and hypothesizing are some of these processes. Terms such as inquiry, problem solving, and the scientific method are also used to refer to process. Not only are these processes important to the scientist, but they are also important to the layman in his day to day thinking. Content refers to information which has been gathered and organized by the scientist, while process refers to the mental activities used by the scientist to gather and organize knowledge.

Science educators have long debated the issue as to whether it is more important to emphasize process or content in elementary school science teaching. Many believe that the issue is really not up for debate since they think that there are many more important arguments for teaching process over content. According to them, the process approach to elementary school science—not the content approach—can be supported by considering the following: (1) History of elementary school science in the United States, (2) Cognitive development of elementary school pupils, and (3) The preparation of elementary school teachers.

The discussion which follows attempts to show why process and not content should be the primary emphasis in elementary school science teaching. The areas which are considered include: (1) The history of elementary school science in the United States. History clearly shows the importance which educators have placed on the scientific method in the elementary school curriculum. (2) Cognitive development. Developmental psychologists believe that pupils should be active inquirers and that learning of factual information is less important than the process of acquiring it. (3) The preparation of teachers. Apparently elementary school teachers can be better trained to teach the processes of science than the content of science.

THE HISTORY OF ELEMENTARY SCIENCE EDUCATION

Historically, science as a process has always been emphasized in elementary science education in the United States. In the days of Object Teaching, starting about 1850, terms such as observation, experimentation and reasoning were often used and found among the objectives of many object teaching curricula. Terms such as doing, observing, inducing, and concluding were used extensively during Liberty Hyde Bailey's Nature Study period. The Nature Study movement started in the late 1800's, continuing through the 1920's. Between 1925-1960 educators stressed problem solving, the scientific method and reflective thinking even though most curricula of the period were subject-matter oriented. Most recently, the national elementary science curricula of the 1960's, especially *Science—A Process Approach*, emphasize processes rather than the content of science. A number of other approaches to the teaching of science in the elementary school were developed during the 1960's, each stressing that children should become involved in the processes or methods of science rather than the facts of science.

What follows is a discussion of elementary science by "era"—that is—from object teaching through the programs of the sixties. This history clearly demonstrates the continuing concern of educators to teach the methods and processes of science to children.

Object Teaching 1850-1880

The main purpose of object teaching was to train children to make accurate observations and to develop their powers of concentration. Educators hoped that this kind of teaching would enable children to think and reason better.[1] Training the minds of children so they would be better thinkers was based on the precepts of "faculty psychology" and the writings of the Swiss educator Pestalozzi.[2] Faculty psychologists asserted, in the 18th and 19th century, that the human mind is composed of many different compartments or faculties. Memory, discrimination, concentration, reasoning, and perception are some of these faculties. According to their views, these faculties functioned independently of each other and could be trained individually.

[1] Underhill, O. E. *The Origins and Development of Elementary School Science.* New York: Scott Foresman & Co., 1941.

[2] Hurd, P. D. and Gallagher, J. J. *New Directions in Elementary Science Teaching.* Belmont, Cl., Wadsworth Pub. Co., Inc., 1969.

Pestalozzi (1746-1827) was in his day the world's most widely acclaimed teacher of the young.[3] He advocated observing, experimenting and reasoning, denouncing the highly verbal and rote memorization techniques that had existed in the classroom.[4] The intellect of the child could, in his view, best be developed if the child would study real (concrete) objects by using all of his senses. The mind and not the learning of facts was the object of educational training.[5] Facts and experiences were important to the training of the mind only if they could be grouped and organized by the learner in a meaningful way. He promoted the idea that children should center their learning around materials and not around books.

As a result of the influence of Pestalozzi and faculty psychology object lessons developed a characteristic methodology. In object lessons pupils were encouraged to make observations on common objects, e.g., animals, plants, and rocks. The idea was not to teach the pupils about objects per se, but to give them practice with this method of learning. Teachers' manuals were available which explained how object lessons might be taught, and in a few places there were efforts to train teachers in this methodology.

Although pupils were encouraged to study objects in their environment and make their own discoveries, "object teaching" resulted in a great deal of teacher talk and often no learning on the part of the pupils. This method of teaching was criticized and was banned in many instances because it lacked order and direction and because it involved meaningless memorization.[6] However, one must keep in mind that most elementary school teachers in the mid 1800's were not trained in science and in fact only relatively few elementary teachers had a college education.

Elementary Science as Nature Study 1890-1920

The Nature Study movement, although characterized by romanticism, contained elements of the scientific method as shown in the writings of Liberty Hyde Bailey.[7] The romanticists felt children should be naturalists. They wanted children to love nature and to be guided by faith and impulse. Children should learn to observe nature at random, not systematically. Hence, the main objective of the romanticists was to promote a fuller life for children through the glorification of nature.

Bailey who was somewhat of a romanticist was given the charge in 1897 to promote agriculture in New York State. Bailey believed the only way to promote agriculture was to get young people interested in country life. He said: "The animus of the endeavor is to cause the child to love nature and thereby be content with country life. There is no other corrective of agricul-

[3]Pestalozzi, H. H. *The Education of Man.* New York: Greenwood Press, 1969, 7.

[4]Op. cit., Hurd, P. D. and Gallagher, J. J., 1969.

[5]Heafford, M. *Pestalozzi.* London: Methuen & Co., Ltd., 1967.

[6]Op. cit., Underhill, 1941.

[7]Ibid.

tural ills."[8] Bailey felt that elementary school children could be taught to be interested in and sympathetic with the natural habitat of the country.

In addition to emphasizing the aesthetic value of rural life, Bailey promoted elementary science education through Nature Study. The Cornell Leaflets[9] which Bailey edited and in which he wrote extensively show an emphasis on the "process approach" to science through the study of nature. In the first Cornell Leaflet Bailey said the following: "Nature Study, as a process, is seeing the things that one looks at, and the drawing of proper conclusions from what one sees. Its purpose is to educate the child in terms of his environment, to the end that his life may be fuller and richer. Nature Study is not the study of science as botany, entomology, geology and the like."[10] Bailey continued by saying that children should make first hand observations of common objects in their environment, such as birds, flowers, insects, and stones. He constantly warned teachers to avoid definition learning and having children always read from books. He felt there was too much telling and explaining in the classroom. Bailey once said that every schoolroom should have a sign saying: "Teaching, not telling."[11]

Elementary Science 1925-1960

Elementary science curricula in the 1920's and 1930's stressed both the processes and the content of science. The main objectives of elementary science teaching emphasized teaching the "scientific method" and the mastery of facts. The literature of this period proposed that pupils perform "experiments". Supposedly these experiments would have required pupils to use the scientific method. However, the scientific method was not clearly understood by most elementary school teachers and was often confused with a series of steps which scientists usually use to report their findings: (a) problem, (b) materials, (c) methods, (d) observations, (e) conclusions, and (f) application. Many teachers mistakenly used these steps to teach the "scientific method."

In 1927 a special committee organized by the American Association for the Advancement of Science issued a report: *On the Place of Science in Education.*[12] This report stated that teaching the scientific method should be an objective of education and that science education could best fulfill this particular goal. John Dewey, whose work influenced this report, extolled the virtues of scientific methodology. He believed that analyzing problems in a scientific way would produce more reflective thinkers, therefore more able citizens.

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[8] Ibid, p. 162.

[9] These leaflets were published at Cornell University where Bailey was a professor.

[10] Bailey, L. H., What is Nature Study? In *Cornell Nature Study Leaflets.* State of New York, Department of Agriculture, Nature Study Bulletin No. 1, Albany: J. B. Lyon, Co., 1904.

[11] Ibid, p. 28.

[12] National Society for the Study of Education. *Forty-Sixth Yearbook, Part I, Science Education in American Schools.* Chicago: University of Chicago Press, 1947.

The Thirty-First Yearbook, Part I of the National Society of Education, "A Program for Teaching Science",[13] deals with the topic of science teaching at great length. In the section on the *Psychology of Science Teaching*, the methods of science are very strongly promoted. This is illustrated by the following statements derived from that source:

1. The aim of science teaching is to promote the well being of the individual by exposure to problem solving situations.
2. Problem situations that can form realistic experiences must constitute the core of the curriculum.
3. The memorization of unrelated facts is not recommended.

In this source, as well as in other literature of this era, the term scientific method was often replaced with terms like problem solving and reflective thinking.

Underhill, in 1941, wrote a lengthy discourse on the history of elementary science education in the United States.[14] She perceived the elementary science movement of the 1930's and 1940's as one which was trying to train pupils to be problem solvers and reflective thinkers. Students were taught to develop the scientific attitude by using the scneitific method. It was hoped that this attitude and this way of thinking could be transferred to other areas in life.

Elementary science curricula in the 1920's and 1930's emphasized science content but stress was also placed on teaching the scientific method to children. *The Thirty-First Yearbook, Part I* contains many examples of the content to use and the rationale for selecting it. The topics were selected from areas like (a) Great Concepts of Science, (b) Health, (c) Economy, and (d) Safety. The content was arranged so that a child could hopefully realize the great scientific principles. One example of such a principle stated in this yearbook is:

> "Living things survive because they are fitted to conditions under which they live and in which their structures and ways of living enable them to attain adult lives and to leave offspring."[15]

Many subordinate principles for grades K-6 were also outlined in *The Thirty-First Yearbook*.

The Forty-Sixth Yearbook, Part I of the National Society for the Study of Education[16] "Science Education in American Schools," published in 1947 presents the objectives of elementary school science showing the emphasis in the 1940's on teaching the scientific method to children. These are as follows:

1. There should be a functional understanding of science information, concepts, and principles on the part of the child.

[13] National Society for the Study of Education. *Thirty-First Yearbook, Part I*, A Program for Teaching Science. Chicago: National Society for the Study of Education, 1932.

[14] Op. cit., Underhill, 1941.

[15] Op. cit., National Society for the Study of Education, 1932, 164.

[16] National Society for the Study of Education. *Forty-Sixth Yearbook, Part I*, Science Education in American Schools. Chicago: University of Chicago Press, 1947, 30-35.

2. The child should acquire instrumental skills like reading in science, making observations and performing other activities in science.
3. Those elements of the scientific method that the child can handle intellectually should be promoted.
4. The child should acquire the scientific attitude.

In the 1940's the processes of science were still emphasized—the literature supports this even though the outcomes showed a content orientation.

Most elementary school science teaching of the 1950's was based on elementary science textbooks. As many as twenty different series of elementary science texts were commercially available during this period. Most of these texts emphasized "experimenting" and "problem solving". They usually presented a sequence of science topics and activities thought to be appropriate for pupils in grades K-6. Science content was to be learned through an activity-oriented approach. However, science lessons in the classroom became reading lessons and lessons where teachers talked about science rather than "doing" science.

The New Elementary Science Curricula of the 1960's

A number of federally funded elementary science programs were developed during the 1960's. *Science—A Process Approach* was one of these. This K-6 curriculum was developed by a team of scientists, science educators, psychologists and teachers. As the name implies, *Science—A Process Approach* focuses upon the processes of science. The processes which are dealt with include observing, communicating, classifying, using numbers, inferring, predicting, hypothesizing, manipulating variables, and interpreting data. Robert Gagne, the psychologist who was very instrumental in constructing the process hierarchy, said this about the program.

> "The most striking characteristic of these materials is that they are intended to teach children the processes of science rather than what may be called science content. The goal of this approach is not an accumulation of knowledge about any particular domain. However, a variety of content is used to support the learning of the process skills.[17]

> "The sixth grader who has learned science processes in this manner should be capable of studying science in the higher grades in a way not now possible, i.e., said student will be able to learn about *any* science, presented in accordance with its theoretical structure, in far less time than would otherwise be required."[18]

Arthur H. Livermore, Deputy Director of the American Association for the Advancement of Science, points out that the major theme of *Science—A Proc-*

[17] Gagné, R., *Elementary Science: A New Scheme of Instruction.* American Association for the Advancement of Science: Miscellaneous Publications, Washington, D.C., 1965, 1.

[18] Ibid., p. 5.

ess Approach (SAPA) is the processes of science, but that these processes cannot be taught in the absence of content. "In a sense, process is the warp and content the woof of the fabric of this elementary science program."[19] Biologists, chemists, geologists, physicists, and psychologists selected content from their fields to be included in SAPA. This resulted in a content distribution as follows: Physical Science 40%, Life Science 25%, Mathematics 18%, Earth Science 25%, and Social and Behavioral Science 7%.[20]

At least ten elementary science programs developed during the 1960's emphasize the processes and content of science to varying degrees. For example, *Science Curriculum Improvement Study* (SCIS) emphasizes content first and then process.[21] The primary aim of this program is to have elementary pupils become literate in science. It tries to accomplish this goal by developing the content of the curriculum according to the following "hierarchy of abstractions;"

1. First level abstractions concern matter, living matter conservation of matter and variation in one property among simple objects.
2. Second level abstractions concern interactions and relativity.
3. Third level abstractions concern energy, equilibrium, steady behavi nd reproduction, and specialization of living matter.

SCIS also places emphasis on the processes of science. Robert Karplus, a physicist, who said that science programs in the schools should develop the scientific point of view[22] was very instrumental in developing this curriculum. Karplus structured each lesson so that the pupils would have an opportunity to observe, invent, and discover. He believes that this approach to learning will aid children in their development toward what Piaget calls the formal operation stage, which is the last and most sophisticated stage of cognitive development.[23]

A number of other modern elementary science programs have also been developed. Many of them emphasize the content of science but also stress discovery and inquiry. For example the *Conceptually Oriented Program in Elementary Science* (COPES) stresses the conceptual schemes or the "great ideas" of science. The *Elementary School Science Project* (ESSP) developed in the early 1960's at the University of Illinois is a curriculum concerned with the modern concepts, theories and methods of astronomy. Even though these programs stress content they still promote the learning of science through discovery and inquiry.

In summary, the history of elementary science education in the United States since 1850 clearly reveals that educators emphasized the scientific

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[19] Livermore, A. H. AAAS Commission on Science Education. *Journal of Chemical Education.* 1966, 43, 70.

[20] Gagné, R. AAAS Miscellaneous Publication 67-12; Washington, D.C., September, 1967.

[21] Karplus, R. The Science Curriculum Improvement Study. *Journal of Research in Science Teaching.* 1964, 2(4), 293-303.

[22] Karplus, R. The Science Curriculum Improvement Study – Report to the Piaget Conference. *Journal of Research in Science Teaching.* 1964, 2(3), 237.

[23] Ibid., pp. 236-241.

method in science teaching. The lists of objectives of science curricula developed from 1850 through the 1960's have consistently included objectives promoting the scientific method. Phrases such as critical thinking, problem solving, and observing, were commonly found among the objectives. There have perhaps been fewer points in educational discussions on which there has been greater agreement than that of the desirability of teaching the scientific method. Generalists in education (not specifically science educators) have also been strong advocates of the scientific method. For example, John Dewey constantly emphasized in his writings the part played by science and the scientific method in the field of general education In 1910 he wrote:

> "One of the only two articles that remain in my creed of life is that the future of our civilization depends upon the widening spread and deepening hold of the scientific habit of mind: and that the problem of problems in our education is therefore to discover how to mature and make effective this scientific habit."[24]

In the thirties, educators continued to concur with Dewey on the importance and place of the scientific method in elementary education.

> "Science has been defined as knowledge at its best, knowledge in its tested and surest form. Science is tested thought, but it is also a method of thinking, not merely one among methods of thinking, but the only method of rigorous, critical thinking."[25]

The Forty-Sixth Yearbook, Part I, of the National Society for the Study of Education published in 1947 summarizes the reports of the Educational Policies Commission and the Harvard Committee on General Education. Both Committees agreed in their major recommendations regarding science teaching. These reports are summarized as follows:

(a) "Science instruction should begin early in the experience of the child.

(b) All education in science at the elementary and secondary levels should be general. Even for students going to college, general courses in biological sciences and physical sciences (according to the Harvard Report) should make a greater contribution to the student's general education and his preparation for future study and *separate* one-year courses in physics and chemistry." The document of the Educational Policies Commission goes even further in its recommendations for reorganization of high school science courses.

(c) The development of competence in use of the scientific method of problem-solving and the inculcation of scientific attitudes *transcend in importance* other objectives in science instruction."[26]

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[24]Dewey, J. Science as Subject-Matter and as Method. *Science*, 1910, 31, No. 127.

[25]Progressive Education Association. Science and General Education. New York: Appleton-Century, 1938. (In the second chapter of this book the implications of science programs are discussed in detail for secondary, college and lower levels. However, most of what is discussed is also important for elementary school science.)

[26]Op. cit., National Society for the Study of Education, 1947, 20.

COGNITIVE GROWTH

OF THE ELEMENTARY SCHOOL PUPIL

Psychologists who have studied child cognition also tend to promote the process approach to learning. Maria Montessori, Jean Piaget and Jerome Bruner are three well-known psychologists who agree unanimously that the methods by which scientists gather, interpret and use information should be taught to pupils. According to these psychologists processes such as classifying, ordering, inferring, measuring, and counting are basic processes in which all pupils should be competent. They seem to agree that children develop intellectually by constantly using and developing these processes and not by learning facts, concepts and principles of a given subject matter area.

Maria Montessori has said: "All men should come under the influence of the scientific method; and every child should be able to experiment at first hand, to observe, and to put himself in contact with reality."[27] She promoted discovery learning and the processes of science in her schools. Communicating, classifying, dealing with spatial relationships, measuring and using numbers were believed basic to intelligence. It was her view that they could be best developed by allowing the child to manipulate materials.

According to Montessori[28] the child's environment is an extremely important variable. She believed children should have certain materials in their environment which were to be used in a certain way. Montessori strove to promote the development of skills or processes which are basic to more advanced mental operations. For example, she insisted that young children (three year olds) hold certain objects in a particular way. Gripping objects would exercise the child's hands so that he would be able to use a pencil when it came time for him to start writing. Blocks used in Montessori's school were of certain sizes. The larger blocks were one liter in volume, the smaller blocks were one cubic centimeter in volume. Initially, the children built towers with the blocks. Later, they were taught volumetric units in the metric system using the same blocks.

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[27] Montessori, M. *Spontaneous Activity in Education.* Cambridge, Mass.: Robert Bentley, Inc., 1965, 244.

[28] Standing, E. M. *The Montessori Revolution in Education.* New York: Schocken Books, 1967.

Montessori believed that pupils in the "ordinary" elementary school sit passively a great deal of the time.[29] The minds of these pupils dwell upon very little except about what the teacher is talking, and that these pupils do very little imagining. In contrast, children in Montessori schools are kept busy manipulating materials, gathering information for themselves and learning cognitive skills basic to scientific inquiry.

Jean Piaget states that children learn and grow intellectually by doing and not by learning factual information and that cognition results from acting on the environment. He believes that aim of education should be to enhance cognitive growth.

According to Piaget "the goal of education is not to increase the amount of knowledge that an individual learns."[30] When children take in information passively or have it impressed upon them non-cognition results instead of cognition.[31]

Piaget states that intellectual development proceeds in a stagewise progression. The stages which he refers to are called the sensorimoter stage (0-2 years), the concrete operational stage (2-11 years) and the formal operational stage (11-adult years). Each of these stages is characterized by the development of certain mental operations. The mind uses these operations to act on, modify and organize the environment.

For the most part elementary school pupils are in the concrete stage of cognitive development. As time goes on, they improve their ability to use concrete operations such as classifying, counting, measuring and seriating. Piaget indicates that these operations are the basis of knowledge and as the children approach adolescence they develop more advanced operational structures which enable them to make hypotheses and deductions. When they have acquired the more advanced structures they are then more receptive to learning by linguistic transmission. By this time these pupils are no longer in the elementary school.

Jerome Bruner believes that elementary school pupils should learn by discovery. He says that discovery, "whether by a schoolboy going on his own or by a scientist cultivating the growing edge of his field, is in its essence a matter of rearranging or transforming evidence in such a way that one is enabled to go beyond the evidence so reassembled to additional new insight."[32] In short, Bruner is saying discovery learning is "figuring out things for oneself."[33]

Bruner cites four benefits for children who learn through discovery: "(1) an increase in intellectual potency, (2) a shift from extrinsic to intrinsic rewards, (3) learning the heuristics of discovery, and (4) aid in memory processing."[34]

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[29] Op. cit., Montessori, 1965, 269.

[30] Duckworth, E. Piaget Rediscovered. *Journal of Research in Science Teaching*, 1964, 2(3), 174.

[31] Langer, J. Implication of Piaget's Talks for Curriculum. *Journal of Research in Science Teaching*, 1964, 2(3), 208-213.

[32] Bruner, J. S. The Act of Discovery. *Harvard Educational Review*, 1961, 31(1), 354.

[33] Ibid., p. 364.

[34] Ibid., p. 353.

For Bruner "knowing is a process not a product."[35] He says we teach subjects to get the learner to take part in the "process of knowledge-getting."[36] The learner should not be a storehouse of information, but a person who knows how to gain and use information.

Bruner[37] suggests that the first two years of school should be devoted to acquiring skills which are basic to mathematics and science. These skills and operations include logical addition, classification, multiplication, inclusion and serial ordering. Bruner feels that if pupils acquire these basic science processes, they will have an intuitive understanding of more advanced mathematics and science concepts.

Psychologists such as Montessori, Piaget and Bruner all appear strongly to agree on the importance of children learning and improving their ability to use the methods of science. They believe that the methods or processes of science are basic to human thought and should be stressed in elementary school teaching. These psychologists de-emphasize the learning of factual material, because they believe it does not promote cognition. They see pupils as active explorers who are learning how to organize and understand objects and events in their environment.

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[35] Bruner, J. S. *Toward a Theory of Instruction.* New York: W. W. Norton & Co., Inc., 1968, 72.

[36] Ibid., p. 72.

[37] Bruner, J. S. *The Process of Education.* New York: Vintage Books, 1963, 46.

THE ELEMENTARY TEACHER IN ELEMENTARY SCIENCE

Content oriented science programs present many problems for the elementary school teacher. In general, elementary teachers find it very difficult to teach science effectively when the emphasis is on content. The teacher's background in biology, chemistry, earth science, and physics is usually too limited to teach a content curriculum. The prospects for elementary teachers receiving adequate training in the major science areas in pre-service or in-service programs seem to be very slim. At present, teacher training institutions do not require prospective elementary teachers to take more than one or two science courses. It is also difficult for in-service training programs to increase the amount of science information teachers need to know without increasing the already heavy loads which elementary school teachers carry. A more dismal picture is presented when one realizes science information accumulates at such a tremendous rate that it would be almost impossible for most elementary teachers to keep up with the knowledge explosion.

When the emphasis is on process rather than content, elementary teachers appear to be more successful in teaching science. Teachers participating in the *Science—A Process Approach* program seem to be competent in teaching the processes of science since pupils are able to achieve most of the process objectives taught in the SAPA program. The attainment of these objectives reflects the success of teachers with this process oriented program.

A review of the literature of elementary science education since 1850 shows that elementary school teachers have had difficulty in teaching science since they lacked both science background and proper training. Underhill[38] in *The Origin and Development of Elementary School Science* points out that the lack of effective science teaching in the elementary school was due to the teachers' inadequate science background. Even today teachers complain that they are not well-prepared to teach science because of their limited content background and training.

Reinisch[39] believes elementary teachers are not prepared to teach science content to elementary school pupils He says that more than ever teachers are

[38] Op. cit., Underhill, 1941.

[39] Reinisch, B. The Need for Science Consultants. *Science Education*, 1966, 50(1), 52-54.

having a difficult time in acquiring an adequate background in the major content areas. The amount of science information being discovered is vast and it would be a full-time job for teachers to keep up with the knowledge explosion.

Thomson and Voeker[40] reported that teachers need a content background to teach the *Science Curriculum Improvement Study* (SCIS) program. SCIS is a national elementary science program which promotes the teaching of process as well as the concepts and principles in biology, chemistry, and physics. Thomson and Woeker believe that teachers will have to participate in in-service programs in order to learn the science content needed to teach the SCIS curriculum.

In-service programs will not necessarily help elementary teachers to keep up-to-date in science. In a paper presented to the American Association for the Advancement of Science, Costa said:

> "The topic 'How Elementary Teachers Keep Up-To-Date in Science' is based on the assumption that this is a goal which can be accomplished. Let us begin by understanding that no one today can keep up-to-date in science. The teacher, above all, has many areas in which to keep up-to-date. The elementary school teacher has responsibilities not only in science, but in reading, social studies, mathematics, health, physical education, and all the related fields taught in the elementary schools. Furthermore, the teacher is asked to keep up-to-date on the current research in child growth and development, learning behavior and psychology, and the sociological impact of his community. So to assume that teachers keep up-to-date in science is from the outset a false assumption. However, their are many opportunities presented to elementary school teachers by which he may increase his awareness of scientific endeavors."[41]

Pre-service training, just as in-service training, does not appear to provide any pat answers for preparing elementary school teachers for content-oriented science programs. Gross and Mayo state: "Science requirements for prospective elementary teachers are usually minimal and it is unrealistic to expect a substantial increase in science training."[42] They do not see substantive or content course training as an answer to better science teaching. However, they do see broad interdisciplinary courses which "emphasize the intellectual nature of science"[43] as being the type of courses prospective elementary teachers should and can participate in. Gross and Mayo's imply that elementary science teaching preparation might best emphasize the processes of science rather than science content.

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[40] Thomson, B. S. and Voeker, A. M. Programs for Improving Science Instruction in the Elementary School. *Science and Children,* 1970, 7(8), 29-37.

[41] Costa, A L. How Elementary Teachers Keep Up-To-Date in Science. *Science Education,* 1966, 50(2), 126-127.

[42] Gross, P. and Mayo, D. E. Preparing the Elementary Teacher for Science: A New Direction. *Science and Children,* 1969, 6(6), 22.

[43] Ibid., p. 24.

Gagné indicates that the content approach could result in teaching science by reading about it, telling, describing and demonstrating and that pupil achievement might be measured solely in verbal terms.[44] He feels that the nature of science as a dynamic on-going, open-ended process of investigating natural phenomenon may be lost by using the content approach. Gagné also thinks this kind of teaching results in learning which will be "incomplete, shallow, verbal parroting and highly ineffective for later learning of the separate scientific disciplines."[45]

Although it is evident that elementary teachers have and will continue to have a difficult time in teaching a content oriented science program, the same may not be true of elementary teachers who are involved in a process oriented program. A look at several evaluation studies on pupil performance in a *Science–A Process Approach* (SAPA) program seems to indicate that teachers are able to handle the process approach. The SAPA program has several behaviorally stated process objectives for each of the many science lessons in grades K-6. Each lesson has a competency measure which can be given to individual pupils. The competency measures provide information as to how well the pupils achieve the process objectives. They also give some information about the success of the teachers in the program.

In an evaluation report on SAPA in 1964 in which pupils were using the first experimental edition of these materials, Walbesser said: "The results of the first try out year when we had about 120 teachers (K-3) in 12 centers teaching the program, were encouraging. On the average, 90 percent of the children tested with the checklist exhibited 90 percent of the desired behaviors. Control children were checked and the best results showed 50 percent of the behaviors."[46]

Walbesser, the following year, performed a follow-up study where he found that approximately 80 percent of the pupils tested attained 80 percent of the process skills.[47] Walbesser attributed the difference in results between the two years to be due mainly to the increased difficulty ofrevised exercises.

Wallace, in an evaluation study of SAPA, in which pupils used the commercial edition, reported that children in grades K-3 during the 1968-69 school year successfully met the goals of an average of 83.9 percent of the exercise competence tasks.[48] The competency tasks were used to measure the attainment of the process objectives in each exercise. His data were derived from a sample of 13,857 pupils in New York State and Pennsylvania elementary schools.

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[44] Gagné, R. The Psychological Basis of Science–A Process Approach. AAAS Miscellaneous Publication 65-8, Washington, D.C., 1965, 10.

[45] Ibid., p. 32.

[46] Op. cit., Livermore, 1966, 27.

[47] Ibid.

[48] Wallace, C. W. Pilot School Competency Measure Report: *Science–A Process Approach*. Syracuse, New York: Eastern Regional Institute for Education, 1969.

In the 1969-70 school year Wallace performed another study involving SAPA.[49] This time. 82.6 percent of the 18,012 pupils participating in the SAPA program were on the average able to meet the performance standards of the competency tasks. The teachers involved in both of Wallace's studies had participated in one-week summer workshops before teaching the SAPA PROGRAM'

In summary, elementary school teachers appear to have more difficulty teaching content oriented science programs than process oriented science programs because their preparation in the major science content areas seems to be very limited. Improving elementary teachers' knowledge in science through pre-service or in-service training does not seem possible. Prospective elementary school teachers in their pre-service training are required to take only a few science content courses. The likelihood of more science courses being required in pre-service training is very slim since the training is already spread too thin. In-service training cannot possibly keep teachers up-to-date in science because of the tremendous rate at which scientific information accumulates. The evidence from evaluation studies on the *Science—A Process Approach* program seems to indicate that elementary teachers are successful in teaching process science to pupils.

[49]Wallace, C. W. ERIE Network Schools Competency Measure Report for the 1969-70 School Year: *Science—A Process Approach*. Syracuse. New York: Eastern Regional Institute for Education, 1970.

SUMMARY AND CONCLUSIONS

Educators have always believed that the methods by which scientists gather and use information are important to teach to children. Pestalozzi in the mid 1800's advocated that children should learn by observing, experimenting and reasoning, but denounced the highly verbal and rote memorization forms of learning. Somewhat later, Dewey strongly emphasized that the methods of science be taught to all pupils. He believed that a scientific attitude would promote more effective citizenry. In 1927 a special committee organized by the American Association for the Advancement of Science, reported that the scientific methods should be an objective of education in general, and that science education could best fulfill this particular aim. Two reports, one by the Educational Policies Commission and the other by the Harvard Committee on General Education in the 1940's agreed that the main objectives of science teaching at all levels include the development of problem solving, the scientific method and the scientific attitude.

In the early 1960's the American Association for the Advancement of Science developed a national elementary science program based on the process approach. The process approach is not only in accordance with elementary science as it has been defined, but it is compatible with what many psychologists feel is important for intellectual growth. Piaget describes the cognitive activities of children in terms of operations which are almost identical with the process skills which people use to collect, organize, test, and explain information. He claims intellectual development progresses through stages and it is only by the use of these operations or processes that intellectual development takes place. Montessori believed that all children should discover and experiment with objects and events in their environment. Bruner emphatically states: "Knowing is process not a product."[50]

Science content is much more difficult for elementary teachers to teach than science process. Elementary teachers, because of their lack of science background, have had and still have a problem teaching many of the facts and concepts in the biological and physical science areas. Even today institutions that prepare elementary teachers do not require that they take more than a few science content and/or science methods courses. With the number of other teaching duties the elementary teacher has, e.g., reading, arithmetic, language arts, and the rate at which the facts of science increases and changes, the elementary teacher could never keep up-to-date with the knowledge of science with in-service training. However, a process oriented elementary science curriculum would not require the elementary teacher to have an extensive content background. There is evidence from a number of evaluation studies performed by Walbesser and Wallace with *Science—A Process Approach* that the elemen-

[50]Op cit., Bruner, 1968, 72.

tary teacher can handle the process approach. Walbesser and Wallace found in their studies that most of the pupils had achieved most of the process objectives.

In conclusion, it seems that there are many reasons why a process-oriented elementary science program can be supported over a content-oriented program. The reasons are as follows:

(1) History of science education from 1850 to the present shows the importance that educators have placed on teaching the scientific method to children. These educators regard the development of competence in use of the scientific method and the development of the scientific attitude the most important objectives of science instruction.

(2) Developmental Psychologists such as Montessori, Piaget, and Bruner believe that child cognition is enhanced when pupils use the processes of science. A great deal of evidence has been gathered to support this point of view.

(3) There is evidence which seems to show that elementary school teachers can be better trained to teach a process-oriented curriculum over a content-oriented one. A content-oriented curriculum requires that teachers understand science concepts and principles as well as keep up-to-date with vast amounts of science information. On the other hand, a process-oriented curriculum requires little understanding of the concepts and principles of science and does not require teachers to keep up-to-date with scientific information. There is data which seems to indicate that teachers can be more easily trained to handle a process-oriented curriculum over a content one since science information is not stressed.

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